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PRINCIPLE OF THE THEORY OF SHIPS ON AN AIR CUSHION (SELECTED CH--ETC(U)
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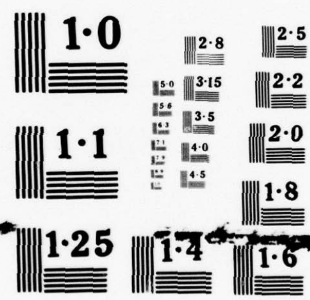
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

PRINCIPLE OF THE THEORY OF SHIPS ON AN AIR CUSHION
(SELECTED CHAPTER SECTIONS)

FOREIGN TECHNOLOGY DIVISION

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PRINCIPLE OF THE THEORY OF SHIPS ON AN AIR CUSHION (SELECTED CHAPTER SECTIONS)

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The setting up of the flexible enclosure/protections even of an small height (to 0.5 m) will lead to the essential decrease of keel tossing during wind agitation. During motion on flat and long waves, the tossing acquires the character, different from tossing during wind agitation. During motion against waves by length λ=1.2-1.5 L_n in the specific speed range the launch falls into the conditions/mode of sharp resonance keel tossing with large spread/scopes and the frequently effective considerable vertical accelerations. During motion along wave, the launch goes smoothly, without falling into the conditions/mode of resonance.

With further increase in altitude of flexible enclosure/protection (to 1 m) the character of keel tossing during irregular agitation will not change, but spread/scopes and vertical accelerations noticeably will be lowered. The greatest amplitudes of keel tossing are observed during motion against wave with low speed. The spread/scopes of keel tossing can reach at this 15-18°. With increase of the running speed, the tossing becomes less intense, spread/scopes do not exceed 5°.

During motion along wave, the spread/scopes of tossing are considerably less; however, the unsuccessful construction of the forepart/nose cell/elements of flexible enclosure/protections can lead to the phenomena of "bending under" ("breaking") of these cell/elements, which lead to a rapid increase in the trim by the bow to dangerous values (collapse). The phenomenon of breaking of the forepart/nose cell/elements of flexible enclosure/protections can occur, also, during motion against wave at a high speed, when these cell/elements, being deformed under the effect of wave, do not manage to be straightened to the approach of following wave. To avoid this, must be provided for the structural/design measures, which eliminate the possibility of breaking of forepart/nose cell/elements in all speed range of course and of centering of SVP during motion on calm water and during agitation.

The separation of the vertical and keel tossing of SVP and examination their independently of each other is admissible only in the first approximation. At the large angles of trim, usually is detected the loss of lift and the caused by this decrease of the height/altitude of soaring/steaming and, consequently, also the displacement/movement of the center of gravity of SVP. Thus, pitching motion, as a rule, it affects the vertical, and therefore it is more

correct to examine the longitudinal tossing of SVP, determined by system of equations:

$$\left(\frac{G}{g} + \Delta M\right)\ddot{y} + 2N_y\dot{y} + \frac{\partial Y}{\partial h}y = \frac{h_v}{2}k_y\frac{\partial Y}{\partial h}\cos(\sigma t - \delta_y);$$
$$(J_z + \Delta J_z)\ddot{\psi} + 2N_\psi\dot{\psi} + \frac{\partial M_\psi}{\partial\psi}\psi = \frac{\partial M_\psi}{\partial\psi}k_\psi\alpha_0\cos(\sigma t - \delta_\psi). \quad (526)$$

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The calculations of the parameters of longitudinal tossing, their amplitude-frequency and phase-frequency characteristics can be made on the basis experimental data, obtained during model tests.

Several words about the problem of the stabilization of SVP during agitation. The statistical materials about the parameters of the tossing of SVP, given are above, with sufficient persuasiveness they show that during action during the agitation of law court on the air cushion is is tested the intense on-board and longitudinal tossing. By completely logical in connection with this is represented the formulation of the problem of moderating the tossing of SVP.

It is known that there are three methods of the stabilization of the vessel:

the structural/design stabilization, attained by the selection of rational measurements and forms;

the natural stabilization, provided with maneuvering (change in the running speed and heading/course angle);

synthetic stabilization - use of dampers of tossing.

Structural/design stabilization of SVP to the greatest degree depends on the measurements of vessel, its displacement, height/altitude and the construction of flexible enclosure/protections, and also the methods of the partitioning of cushion and of the volumetric flow rate of air. The range of the variation of these cell/elements and of the parameters at design is very limited; therefore structural/design stabilization does not always give the necessary effect. Are limited possibilities and natural stabilizations. It is most reliably it is possible to solve task, utilizing dampers of tossing.

On there are no floating and projected SVP of the dampers of tossing; however, familiarization with patent information gives grounds to confirm that questions of the stabilization of SVP seriously are studied.

In accordance with classification [58] the dampers of tossing

are divided into

active or passive - depending on contrcl capability by them and consumption by them external energy;

gravitational, hydrodynamic and hydroscopic - depending on the source of the force, which realize/accomplishes stabilization;

damping (increasing the damping force), that balance (balancing perturbing force) and frequency (changing the natural frequency of vessel) - depending on that, as they will change the susceptibility of vessel to disturbance/perturbations;

the dampers of on-board, keel and vertical tossing - depending on the plane of action.

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It is possible to assume that to SVP will find use in essence the active and in smaller measure passive dampers of tossing. Unlikely is represented the use of gravitational dampers with liquid cisterns. Is most promising, apparently, the application/use of following three types of the dampers of the tossing:

1) the aerodynamic controlled diving rudders, establish/installed after propellers, working in airflow from screw/propellers. With symmetrical relative to center-line plane location the aerodynamic controllers capable of providing effective moderation of the rolling action. With the location of the aerodynamic controllers in their forage it is possible to utilize, also, as the dampers of keel tossing.

Thus, aerodynamic diving rudders in their rational location and the matching system of control can become the universal dampers, which ensure moderation of the spread/scopes of on-board and keel tossing.

2) Dampers of tossing, instituted on pressure adjustment in different sections of the air cushion. Regulating air supply from fans in the section of the air cushion, it is possible to create righting moment, which compensates for the moment of the external forces, which effect both in longitudinal and in transverse plane.

Thus, and this type of the damper of tossing [1] is universal, that ensures moderation of on-board and keel tossing.

FOOTNOTE [1]. For the first time this type of the damper of the tossing of SVP was proposed by Yu. Yu. Benua. See also the patent of France

cl. V60 No 1476633, 1967. ENDFOOTNOTE.

Its basic advantage is the use as operating unit of regular superchargers. External energy will be required only for the drive of the adjustable shutter/valves in air-distributing channels.

3) Hydrodynamic dampers of tossing - controlled or unguided ocntrols, which represent by itself the low-aspect-ratio wings, working in the incident fluid flow. These dampers can obtain the application/use on of special SVP cf the compound configuration, basic part of lift of which is created by the air cushion, and wing systems are utilized for an improvement in stability of motion and moderation of tossing.

The hydrodynamic dampers of tossing can be used, also, to SVP of class B with arrangement/position bringing in on-board boats.

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In this case the construction of controls can be close to the construction of the on-board controls of the water-displacing vessels.

One should expect that within the next few years to the

stabilization of SVP will be allotted the considerable attention.

§31. Drag-rise characteristics and deceleration of course during motion during agitation.

Drag-rise characteristics during motion during agitation is caused by interaction of the housing of SVP and of its inflatable flexible enclosure/protections with waves, and also that fact that reactive component resistance to motion (representing itself the horizontal projection of the resultant of air pressure on bottom) with the large spread/scopes of keel tossing periodically reverses the sign, predetermining the nonuniformity of forward motion. Interaction of the rigid housing of SVP with wave can occur during motion on the waves of high altitude either with the incidence/impingement into resonance tossing, and also in cases when due to the low altitude of flexible enclosure/protections, their unsuccessful construction or as a result of the undercapacity of fans vessel with the passage of waves "loses" cushion, since air losses on perimeter and especially in areas, which correspond to wave trough, considerably exceed a quantity of air, which enters from fans. In these cases are possible the strong blows of housing against a surface of water and a sharp increase of resistance to motion.

The height/altitude of flexible enclosure/protections and fan

capacity are selected during design so that would be eliminated the impact/shocks of housing against water and its interaction with wave during motion under the assigned/prescribed conditions of waviness. Then drag-rise characteristics is determined only by interaction of flexible enclosure/protections with waves and the character of the effect by reactive component.

During motion during agitation, the flexible enclosure/protections of elastic are deformed under the action of waves. To avoid the mechanical contact of flexible enclosure/protections with waves is virtually impossible, but during correct construction it is possible to considerably decrease the appearing during such an interaction resisting forces to motion. Theoretically the resistance, which appears during interaction of flexible enclosure/protection with water, defined; therefore during design this resistance is considered as comprising of permanent hydrodynamic drag, recounted during transition from model to nature according to the law of mechanical similarity with equality Froude numbers.

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Sometimes, disposing of sufficient experimental material, it is possible to isolate the resistance of interaction of flexible

enclosure/protections with water into separate that comprise of total resistance. So, during the years 1964-1965 on the basis of testings of SVP VA-3 by the firm Republic was derived empirical formula for determining the drag coefficient of the flexible enclosure/protection

$$C_{x\,r.o} = 6{,}6\left(\frac{h_{в}-2t}{L_{п}}\right)^{1{,}2}.$$

Formula is used under the condition

$$0{,}005 < \frac{t}{L_{п}} < \frac{1}{2}\frac{h_{в}}{L_{п}} \overset{(1)}{и} \frac{h_{в}}{L_{п}} < 0{,}1,$$

Key: (1). and.

where $h_{в}$ - wave height, m;

t - average on perimeter the value of the clearance between flexible enclosure/protection and shield, m;

$L_{п}$ - length of the air cushion, m.

For VA-3 with $L_{п} = 15$ m, t=0.02 m and to wave height $h_{в} = 1{,}0$ м $c_{x\,r.o} = 0{,}25$. In speed VA-3, equal to 113 km/h (31 m/s), this corresponds to an increase in the resisting force on 1170 kg.

During the research design of SVP abroad, is applied another formula

$$\frac{R_{r.o}}{G} = \frac{\rho g}{2}(\mathrm{Fr})^2 \cdot 3{,}3\left(\frac{G \cdot h_{в}}{L_{n}}\right)^{1{,}2} \cdot \left(\frac{p_{п}}{L_{n}}\right)^{-1},$$

where Fr - Froude number;

p_n - pressure in the air cushion, lb/ft²;

G - weight of SVP, m;

L_n - length of the air cushion, feet;

h_n - wave height, feet.

The resistance to motion of SVP during agitation depends on length and wave height, heading/course angle, speed of running, rate of discharge of air. Figures 183 gives dependence of the resistance of SVP SKMR-1 on regular agitation from the enumerated parameters, obtained according to test results in basin.

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The examination of these dependences makes it possible to make the following conclusions:

a sharp increase of resistance occurs during motion against waves and at acute heading/course angles;

the greatest value of resistance it reaches during motion against waves by the length $\lambda = 1,2 \div 1,5\ L_n$;

with further increase of wavelengths resistance to motion is decreased and becomes the approximately equal to resistance during motion by log to wave;

during motion on waves with $\lambda = 1 \div 2\ L_n$ resistance intensely grow/rises with an increase in the running speed;

an increase in altitude of wave leads to a proportional increase in the resistance;

an increase in the air flow rate makes it possible to sharply lower resistance to motion during agitation.

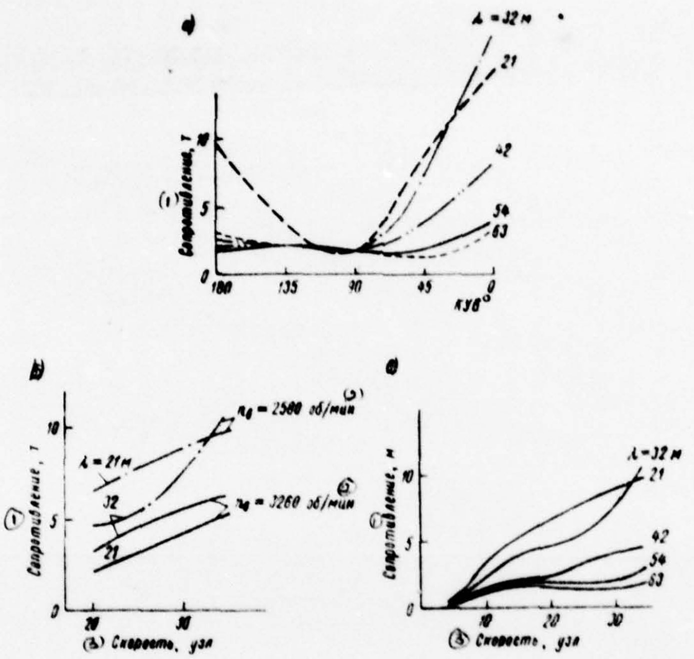

Fig. 183. Dependence of resistance to motion SKMR-1 during agitation on different parameters: a) on KUV; b) on the fan capacity and running speed; c) on the wavelength and running speed.

Key: (1). Resistance, t. (2). r/min. (3). Speed, knots.

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Resistance to motion during agitation depends to a considerable extent also on the construction of flexible enclosure/protections and

on the centering of SVP. Figures 184 gives constructed for experimental SVP of the dependence of relative supplementary resistance during agitation on wave height with different Froude numbers. These dependences are characteristic only for the specific construction of flexible enclosure/protection, specific volumetric flow rate of air and ratio of pressure in flexible receiver to pressure in cushions, ~1.2.

An increase in the resistance leads to considerable deceleration of the course of SVP during agitation.

The given to Fig. 185 dependences of the speed of running of SVP on the intensity of agitation show that during the agitation of 3 points the speed of running of launches SRN5 and SRN6 falls on 20-30o/o. During the agitation of 3-4 points also is substantial deceleration of course SRN4 - largest of foreign SVP.

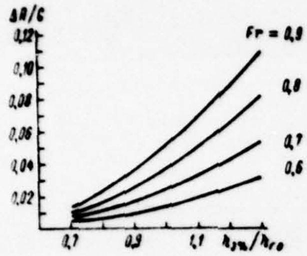

Fig. 184.

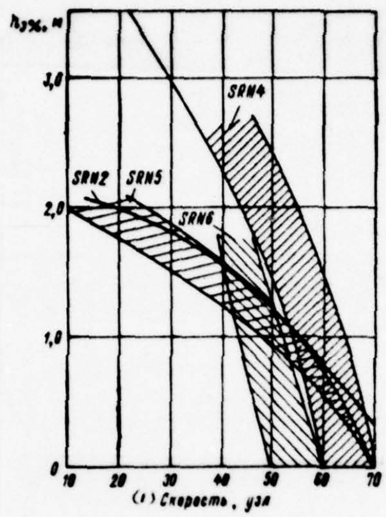

Fig. 185.

Fig. 184. Dependence of relative supplementary resistance during agitation on wave heights and running speed.

Fig. 185. Air cushion vehicles seaworthiness.

Key: (1). Speed, knots.

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Figures 186a gives the dependences of resistance to motion on speed of course and wave heights, designed for promising SVP by displacement 1000 t, while Fig. 186b depicts the dependences of the resistance for promising SVP by displacement to 10000 t.

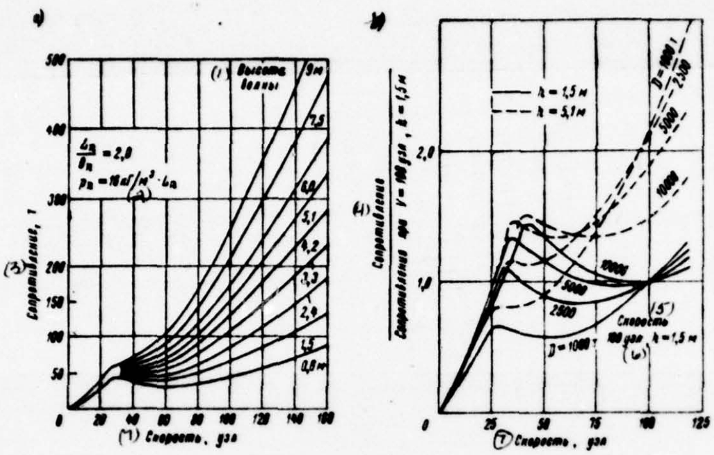

Fig. 186. Dependence of resistance to motion of promising SVP of class B on wave height and running speed: a) SVP by displacement 1000 t; b) SVP by displacement from 1000 to 10000 t.

Key: (1). Wave height. (2). kgf/m². (3). Resistance, t. (4). Resistance/resistance with V=100 knots, h=1.5 m. (5). Speed. (6). knots. (7). Speed, knots.

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§32. Vertical accelerations, which effect on SVP during motion during agitation.

During motion even on the short waves, which compose only the

part of the length of the air cushion, SVP is is tested effect of the accelerations of low amplitude and high frequency. The air cushion which, it would seem, must damp the slight disturbances and absorb the accelerations of low amplitude, transfers them to housing. This somewhat an unexpected phencmenon explained by Cockerell [64].

Let us examine, for example, the motion of rectangular in the plan/layout of SVP, in cushion of which pressure are 300 kgf/m². Vessel goes against waves with a length of $\lambda = 0.4 L_n$. In a moment for the extent/elongation of the length of the air cushion under vessel, are located three apex/vertexes and two wave troughs, while at following torque/moment wave system will move and under vessel will be already two apex/vertexes and three bottoms. If during this displacement/movement the volume of cushion changed only to 1o/o, then this will lead (we consider the duct/contour of the air cushion closed) to a change of the absolute pressure in cushion on 1o/o, i.e., on 106 kgf/m² (10330+300/100). But 106 kgf/m² will be 1/3 pressures in cushion, and the appearance of this pressure will lead to the emergence of the effective on SVP acceleration, equal to 1/3 g. During a change in the form of SVP and during transition from rectangular to form with the pointed forepart/nose tip and rounded stern the sensitivity of vessel to the disturbance/perturbations, caused by short waves, is decreased. During motion on the longer waves of a change of the volume of the air cushion in certain cases,

they can be large, and acceleratiors will increase. Accelarations, which effect on SVP, caused not only change in the volume of cushion and by the caused by it change in the pressure, but also by the parameters of longitudinal tossing.

As is known, there are physiological thresholds of the perception of the accelerations of the tossings after which of man begin to be developed and tc progress the symptcms of sea-sickness. Especially intensely sea-sickness is developed during vertical accelerations more than 0.1 g and rotary accelerations more than 3 deg/s². The value of the permissible vertical accelerations is designated depending on the extent of route and the frequency of the appearance of accelerations. In England the tclerance level of accelerations for passenger SVP is accepted equal to 0.1 g at frequency 2 Hz and are not more than 0.2 g at the frequency of less 1 Hz. If the extent of route does not exceed 8 miles, are considered permissible vertical accelerations to 2 g. For SVP of military designation/purpose, the tolerance level of accelerations also can be built up to 2 g.

The prospect of passenger air cushion vehicles to a considerable degree depends on that, be managed to solve the problem of the tossing of these vessels and to ensure the normal accelerations, permissible according to the conditions of comfort. In connection

with this in England, were carried out the investigations of the dependence of accelerations on displacement and measurements of vessels, the height/altitude of flexible enclosure/protections, the power of fans and the speed of running [64]. The results of these investigations are given to Fig. 187, and also to Fig. 188-192.

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Figures 187 shows climbing range of the bottom of housing from bearing surface depending on the speed of running and parameters of agitation when the vertical accelerations of SVP must not exceed 0.5 g.

It is possible to conclude that for providing the assigned/prescribed level of accelerations minimum climbing range during motion on any waves up to 300 m in length must be 3 m - with speed of 100 knots, 1.8 m - at speed 50 knots and 1.2 m - at speed 25 knots. Since according to the conditions of providing the stability climbing range cannot exceed 1/6 width of SVP, then to height/altitudes 3; 1.8 and 1.2 m will correspond the widths of SVP with respect 18, 11 and 7.2 m. After accepting as prototype SVP with relation L: B=2, is not difficult to determine length SVP, and then according to the law of similarity to find displacement.

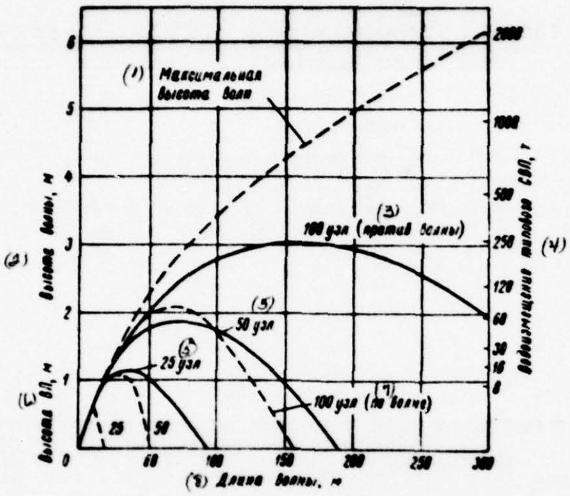

Fig. 187. Climbing range cf the housing of SVP from water surface, necessary for providing the normal accelerations $W \leqslant 0.5$ g.

Key: (1). The maximum altitude of waves. (2). Height/altitude of wave, m. (3). 100 knots (against wave). (4). Displacement of standard cf SVP, t. (5). knots. (6). Height VP, m. (7). knots (on wave). (8). Wavelength, m.

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As a result it was establish/installed that the permissible level of the vertical accelerations of tossing 0.5 g can be provided:

in motion with speed to 100 knots - for SVP by displacement 250 t at climbing range 3 m;

in motion up to 50 knots in speed - for SVP by displacement 60 t at climbing range 1.8 m;

in motion up to 25 knots in speed - for SVP by displacement 20 t at climbing range 1.2 m.

In Fig. 188 the same dependences are designed on the basis of permissible level of accelerations 0.1 g. To SVP by the displacement more than 1000 t this level of accelerations can be provided at the running speed to 100 knots at climbing range of housing more than 5 m; to SVP by the displacement of more than 500 t - at the running speed to 50 knots at climbing range of approximately 4 m, while to SVP by displacement of approximately 150 t - at the speed of running of 25 knots.

However, in order to achieve the assigned/prescribed level of vertical accelerations, it is insufficient to select the measurements of SVP and climbing range in accordance with the recommendations, given to Fig. 187 and 188.

The form of housing, internal air channels, the

relationship/ratio of pressures in receiver and in cushion, construction and the material of flexible enclcsure/protections must be selected so as to ensure sufficient rigidity and at the same time the adaptability of an entire hoisting system.

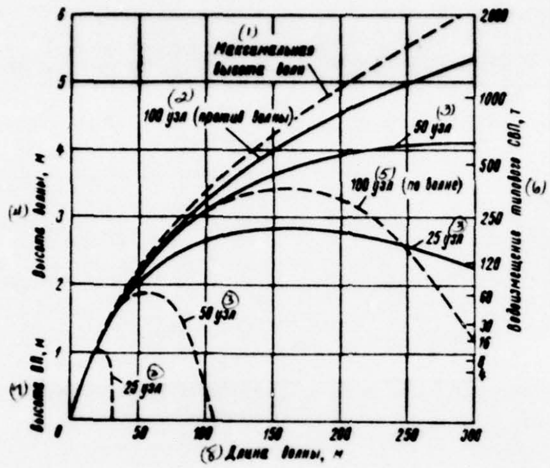

Fig. 188. Climbing range of housing of SVP from water surface, necessary for providing the normal accelerations $W \leqslant 0.1$ g.

Key: (1). The maximum altitude of waves. (2). 100 knots (against wave). (3). knots. (4). Wave height, m. (5). 100 knots (on wave). (6). Displacement of standard of SVP, t. (7). Height VP, m. (8). Wavelength, m.

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And that is especially important, must be provided the sufficiently high volumetric flow rate of air for the compensation losses with tossing.

At the first stages of the design of SVP, the volumetric flow rate of air is determined on the basis of the provision for the best running qualities of vessel on calm water.

As noted in chapter IV, the curve of the dependence of the resistance to motion of vessel on calm water on the air flow rate has its optimum. It is experimentally establish/installed that this optimum for SVP with flexible enclosure/protections of the type flexible nozzle corresponds to average on perimeter gap length between the bearing surface and the flexible enclosure/protection, equal to 0.004 L_n. For SVP with open type transverse-separated cell/elements the optimum ratio of gap length to the length of SVP, it can render/show considerably less; therefore for providing the running qualities of SVP, there is no need for increasing clearance with an increase in the displacement.

That determining when selecting of pressure setting up is now the requirement of the provision for a volumetric flow rate of the air, which corresponds to the conditions of seaworthiness. This flow rate must be sufficient for the compensation periodic air losses with the tossing of SVP.

Figures 189 gives given data, that characterize the volumetric flow rate of air for SVP of different displacement. It is possible to

note that the dimensionless parameter, which represents by itself the ratio of the volumetric flow rate of air to the volume of the air cushion, divided into the period of natural bouncing of SVP, does not depend on displacement. The greatest volumetric flow rate of air can be determined by the following formula:

$$Q = 1{,}5 S_{\text{п}} h_{\text{г.о}} \frac{1}{2\pi} \sqrt{\frac{g}{h_{\text{г.о}}}} \approx 0{,}75 S_{\text{п}} \sqrt{h_{\text{г.о}}},\ \text{м}^3/\text{сек}^{(1)}. \quad (527)$$

Key: (1). m^3/s.

The investigations, carried out in England, will make it possible to establish/install the dependences between the fan capacity and the level of vertical accelerations during the motion of SVP during different agitation with the different running speed.

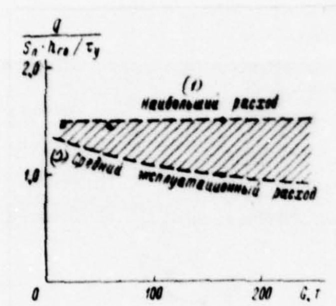

Fig. 189. Dependence of the relative air flcw rate on the displacement of vessel.

Key: (1). Greatest flow rate. (2). Average cperating costs.

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These dependences are given to Fig. 190, 191, and their examination makes it possible to make the following conclusions:

at the speed of running of 50 knots for vessels of cushion of approximately 40 m in length and the displacement of approximately 250 t of acceleration they will not exceed 0.5 g, if the specific power of fans is 40 hp/t;

for providing the accelerations 0.1 g the necessary specific pcwer cf fans grow/rises to 65 hp/t;

for vessels by displacement of approximately 2000 t of cushion of approximately 80 m in length the specific power of fans will be lowered respectively to 20 and 45 hp/t;

at the speed of running of 100 knots, the specific power of fans, necessary for providing the assigned/prescribed level of accelerations, sharply grow/rises and comprises at the length of SVP of approximately 40 m (G=250 t) from 100 to 120 hp/t, while at length of approximately 80 m (G=2000 t) - from 60 to 90 hp/t.

It is completely obvious that the power of fans, necessary for providing the assigned/prescribed level of vertical accelerations at speed 100 knots, exceeds the limits technical capabilities. To SVP with this running speed, can be provided for only considerably smaller specific power of fans, and therefore they will have limitations on the speed depending on the intensity of agitation.

One must not fail to note that the characteristic of the power of fans, necessary for providing SVP of the vertical accelerations, which do not exceed 0.5 g (Fig. 19C), prove to be even at speed 50 knots higher than in practice the designs accepted.

So, the specific power of fans, established/installed on English SVP SRN6 and SRN4, comprises respectively 28 hp/t and 25-40 hp/t.

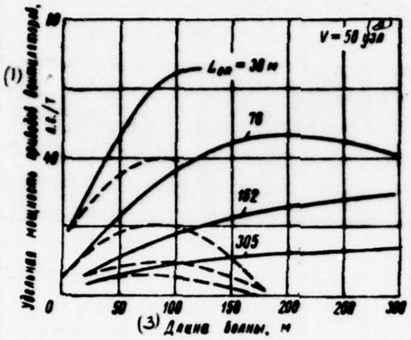

Fig. 190. Specific driving power of fans of SVP, necessary for providing the assigned/prescribed level of normal accelerations during motion 50 knots in a rate of.

—— acceleration W≤0.1 g;

- - - - acceleration W≤0.5 g.

Key: (1). Specific driving power of fans, hp/t. (2). knots. (3). Wavelength, m.

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Taking into account that the specific power, necessary for providing the assigned/prescribed level of accelerations, is decreased with an increase in the linear measurements of SVP, it is

possible to design the power of fans which would be required for air-cushion crafts. This power will comprise for SRN6 about 60 hp/t, and for SRN4 - about 50 hp/t.

However, this essential decrease of the actually available specific power on of floating SVP in comparison with calculated for providing the accelerations W≤0.5 g will not lead to a considerable deterioration in seaworthiness SRN6 and SRN4. In connection with this the dependences, given to Fig. 190-191, can be considered as desirable maximum.

Utilizing the law of similarity and being based on test data of models of SVP during irregular agitation, it is possible to predict the seaworthiness of promising air cushion vehicles. Such investigations were carried out in England, and they will make it possible to establish/install the dependence of the seaworthiness of SVP on displacement and the running speeds on the tolerance level of vertical accelerations 0.5 g and of power-weight ratio of approximately 100 hp/t (Fig. 192).

The examination of these dependences makes it possible to make the following conclusions:

on the assigned/prescribed level of the allowable accelerations

of law court on the air cushion by displacement to 120 t they can emerge in sea during agitation to 4 points inclusively; during more intense agitation (5 points) their determination in sea is admissible according to safety conditions, but the level of vertical accelerations in this case will exceed 0.5 g;.

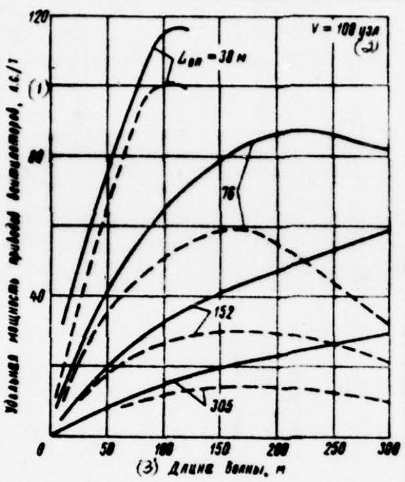

Fig. 191. Specific power of fan drives for SVP, necessary for providing the assigned/prescribed level of normal accelerations during motion 100 knots in a rate of.

—— acceleration W⩽0.1 g;

- - - - acceleration W⩽0.5 g.

Key: (1). Specific driving power of fans, hp/t. (2). knots. (3). Wavelength, m.

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vessels with displacement 250-500 t can move with speed to 60-80 knots during the agitation of 5 points, and accelerations in this case will not exceed 0.5 g;

only large vessels with displacement of approximately 2000 t capable they will be of moving at a high speed of course in the high sea under storm conditions.

Let us note that the given dependences are constructed for the vertical accelerations of tossing 0.5 g and do not characterize entirely the seaworthiness of ships and air cushion vehicles. The limits of the safe floating of SVP lie/rest considerably curves given higher than; therefore with certain digression from the level of the permissible accelerations (to 1-2 g) of the characteristic of seaworthiness, they can be substantially improved. As confirmation of this can serve the graphs of the seaworthiness of SVP, given to Fig. 185. And still one the observation: dependences in Fig. 192 are constructed for the most adverse state of motion against wave. During motion at other heading/course angles of the characteristic of seaworthiness, they will be considerably best.

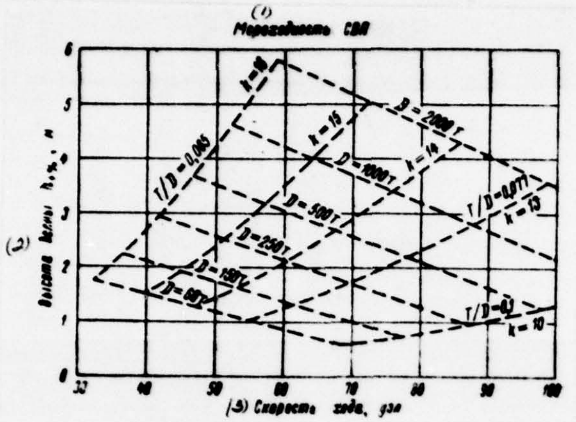

Fig. 192. Seaworthiness of promising SVP (normal accelerations W≤0.5 g).

Key: (1). SVP seaworthiness. (2). Height/altitude of wave. (3). Speed of running, knots.

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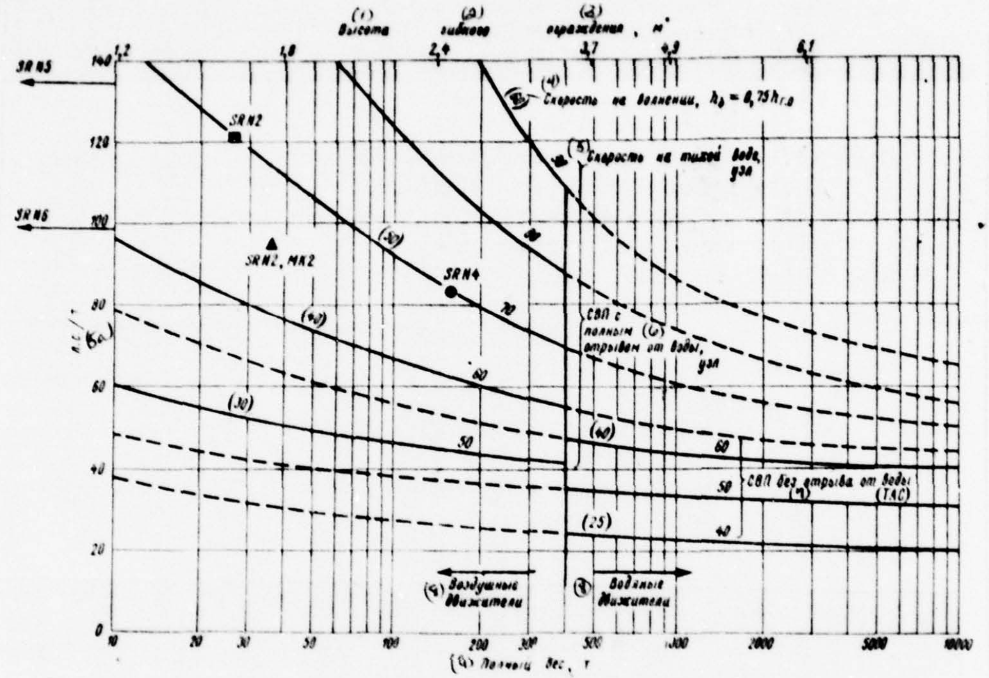

Fig. 193. Change of power-weight ratio of SVP depending on displacement and running speed on calm water and during agitation.

Key: (1). Height/altitude. (2). flexible. (3). enclosure/protection. (4). Speed during agitation. (5). Speed on calm water, knots. (5a). hp/t. (6). SVP with complete breakaway from water, knots. (7). SVP without breakaway from water. (8). Air motors. (9). Gross weight, t.

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The more total characteristic of the expected seaworthiness of promising SVP give the given in R. Stanton-Jones' known work [75] dependences of seaworthiness (by characterizable wave height of the 4o/o security, with which it is possible action of SVP 50 knots in a velocity of) on displacement and power-weight ratio (Fig. 193) and also a graph of the power-weight ratio of SVP with an increase in the displacement (Fig. 194). During the construction of these graphs, was accepted the assumption that SVP with air motors they can be created with displacement to 400 t; with larger displacement to SVP, must be provided for the setting up of water motors (screw/propellers, jets).

Graph in Fig. 193 makes it possible to make the following conclusions:

for SVP with displacement to 400 t the increase of power-weight ratio from 60 to 100 hp/t leads to the proportional increase of seaworthiness;

for the increase of the running speed during agitation from 50 to 60 knots it is necessary to increase power-weight ratio of SVP 1.5 times.

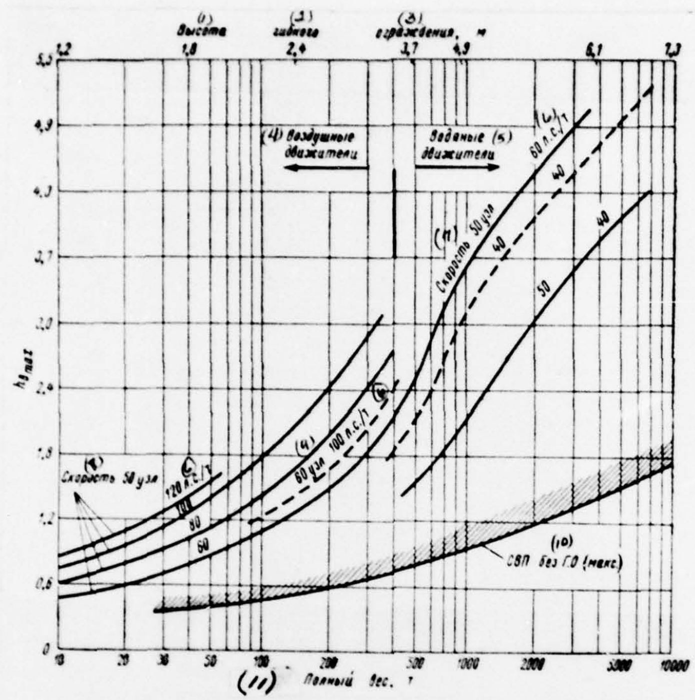

Fig. 194. Seaworthiness of prcmising SVP.

Key: (1). Height/altitude. (2). flexible. (3). enclosure/protection, m. (4). Air motors. (5). Water motors. (6). hp/t. (7). Speed 50 knots. (8). Speed 50 knots. (9). 60 knots of 100 hp/t. (10). SVP without G.O (max.). (11). Gross weight, t.

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Figures 194 gives the dependence of the required power-weight

ratio of promising SVP on displacement and running speed. On graph are plotted/applied the points, which correspond to power-weight ratio, the running speed and the seaworthiness of contemporary SVP. From curve/graph it is evident that the required power-weight ratio of SVP substantially descends with an increase in the displacement. So, for providing the running speed on calm water of 70 knots power-weight ratio of SVP by displacement 20, 200 and 1000 t must reach with respect 130, 80 and 60 hp/t. During motion against the waves whose height/altitude is 3/4 height/altitudes of flexible enclosure/protection $(h_{4\%} = 0.75\ h_{\text{г. о}})$, will be provided speed to 20-30 knots less than during motion on calm water.

§33. Swamping and spraying of SVP.

Swamping and spraying of the water-displacing vessels is caused in essence by the keel tossing, accompanied by the impact/shocks of forepart/nose tip against wave and by the incidence/impingement of the masses of water to deck. Unlike swamping and spraying of the water-displacing vessels the basic source of spray formation during the motion of air cushion vehicles is the outflow of air from the zone of elevated pressure, which leads to formation around SVP of the film (curtain) of spray. In hovering of launch on cushion (without course) this film is almost vertical. During motion in pre-swell conditions/mode, splash/spatter curtain in forepart/nose tip

gradually disappears. In post-swell conditions/mode with an increase in speed of splash/spatter curtain is displaced into stern and becomes ever flatter. At high running speeds, splash/spatter film is retained in the form of the narrow tail, which begins approximately during midsection. During motion with cross wind, splash/spatter curtain of windward board is related by wind to the rear portion of SVP.

Spraying considerably grow/rises during the motion of SVP against wave and wind by the low speeds of the course when intense pitching action leads to large vertical movement of forepart/nose tip and contributes to the inrush/breach of the large masses of air forward. With an increase in the velocity of running speed during agitation, spraying substantially is decreased.

At low temperature spray formation leads to the icing over of housing and protruding parts. Propellers, fans and flexible enclosure/protections, as a rule, in this case do not become covered with ice.

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Spray formation intensely grow/rises with an increase of the pressure in cushion. Let us note that the process of spray formation

is not simulated; therefore it is not possible on the data model testings to determine the intensity of spray formation. In Fig. 12 it is possible to see splash/spatter tail, which is formed during the motion of SVP SRN3.

§34. Special feature/peculiarities of nautical model tests of SVP.

During the design of full-scale SVP to simulation experiment is given the special importance, since model test makes it possible to study their behavior during motion during regular and irregular agitation with different speeds on different courses relative to wave. During these testings is investigated the altitude affect and wavelength on the parameters of the motion of model, and also the dependence of seaworthiness of SVP on the volumetric flow rate of air, centering of vessel, construction, material and size/dimensions of flexible enclosure/protection. During model test, is checked also the correctness in project of the architectural solutions accepted and relationship/ratios of main measurements.

The scales of models can be different - from 1/20 to 1/2. During the creation of models they do not only observe geometric similarity, but also they attempt to ensure the similarity of mass distribution, air pressure in receiver and the air cushion, or the volumetric flow rate of the air through fans.

Testings are conducted on the towed or self-propelled models. Simulation is produced by the observance of equality Froude numbers model and full-scale vessel. Since resistance is partially caused by the friction of the flexible enclosure/protection, which contacts with water, simulation according to Froude is not precise.

During testings of the towed models, are provided three degrees of freedom: is allow/assumed the possibility of oscillation/vibrations on vertical line and around axle/axes OX and OZ. Self-propelled models possess six degrees of freedom; therefore their testings give the most reliable and complete material.

It follows to consider that if during testing of self-propelled models the vector of detent changes direction with keel tossing, then during testing of the towed models this vector retains its direction. Thus, during towing tests substantially are disrupted the conditions of simulation. But if we consider that during motion during agitation the resistance of SVP it is changed with the passage of waves, and consequently it is changed and speed, then it will become obvious, that during towing tests with constant velocity are disrupted the conditions of simulation for the value of detent and its direction relative to model.

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All this leads to the essential difference for kinematics of the motion of the towed and self-propelled models under identical test conditions. So, the spread/scopes of keel and vertical tossing during towing tests prove to be considerably greater than during self-propelled testings.

Therefore in order to obtain the sufficiently reliable data on the tossing of SVP and to evaluate its seaworthiness, it is necessary to carry out self-propelled model tests during irregular agitation.

When conducting of seaworthiness trials of large-scale self-propelled models, appear the specific problems whose solution requires the creation of special metering equipment and development by the person of the measuring technique.

First this problem - measurement of speeds. The rates of the motion of SVP relative to water and relative to air under actual conditions are different. Taking into account that the acting on SVP aerodynamic forces (including the force of pulse resistance) depend on air velocity, and flow forces - from speed relative to water, for

the correct determination of forces, it is necessary to know the values of these velocities. Metering equipment must record/fix value and sense of the vector of speed relative to water and air.

In the practice of seaworthiness trials, the speed relative to water is determined by the Doppler meter, which fixes the rate of the forward motion of SVP along axle/axes Ox and Oz. Speed can be determined also during the use of a system of external measurements - coast motion picture theodolite posts, which lead synchronous photography of SVP in the trajectory of motion, or aerial reconnaissance of the displacement/movements of SVP of the relatively fixed/recorded on water base.

Taking into account the great effect of the drift of SVP of relatively water surface on the forces, which effect on vessel, the measurement of drift angle, equal to $\operatorname{arctg}\frac{V_z}{V_x}$, must be produced with high accuracy/precision. In the practice of road tests, it is accepted that the drift angle must be maintain/withstood by driver within limits of $\pm 2-5°$ and the accuracy/precision of the determination of those composing speeds along the axes Ox and Oz must provide the determination of drift angle with error not more than 1°.

The rate of motion relative to air can be measured only by equipment, establish/installed on board SVP.

on the assigned/prescribed level of the allowable accelerations

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The usual meters of the airspeed, used on aircraft, for determining the speed of SVP do not befit, since they record/fix only composing speeds along the axis x and do not make it possible to determine the vector of airspeed. Therefore during testings of SVP, it is necessary to establish special equipment for the measurement of speed and direction of incident in SVP air flow. Special attention must be directed to the selection of place for the setting up of the receivers of equipment, which measures airspeed, since it is necessary to eliminate the effect of housing and air flow in area of screw/propellers and air intakes of fans on reveicers of this equipment.

The increased requirements must be produced to the accuracy/precision of the measurements of the angle of trim. It is known that during a change in the trim difference on 1° resistance to motion changes to value $G\psi = 0.0175G$. If one considers that during motion on cruising speed the hydrodynamic quality of SVP comprises approximately 7-10 and, therefore, resistance equally to 0.14-0.10 G, then obviously that during a change in the trim difference on 1° resistance to motion can change to 12-18o/o. Therefore for

determining the forces, acting on SVP, with accuracy/precision 1-2o/o it is necessary the trim difference to measure with accuracy/precision of 0.05-0.1°. Since to ensure simultaneously the similarity of hydrodynamic and aerodynamic forces is impossible, then the conditions of the equilibrium of the towed model differ from the conditions of the equilibrium of self-propelled model and full-scale SVP, and the angles of running trim in position of equilibrium are not equal (effect of the thrust of motors is compensated for by the displacement of the center of gravity of model).

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